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# Methods in Paving Contracting

Civil Engineering

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# METHODS IN PAVING CONTRACTING

BY

EVART MONTGOMERY WATKINS

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# THESIS

FOR THE

DEGREE OF

BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1911

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UNIVERSITY OF ILLINOIS

May 25, 1911

I recommend that the thesis prepared under my supervision by EVART MONTGOMERY WATKINS entitled Methods in Paving Contracting be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

G. W. Pickels Jr.
Instructor in Civil Engineering.

Recommendation approved:

Ira O. Baker.
Head of the Department of Civil Engineering.

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# INTRODUCTION.

"Good pavements are necessary to the highest development of the commercial, sanitary, and ^a esthetic life of the city. The large proportion of people now dwelling in cities makes the subject of pavements an important one at present; and the fact that the urban population is increasing much more rapidly than the rural, and also the fact that the public is awakening to the necessity of ameliorating the condition of life in the city, will make pavements of increasing concern in the future".- Prof. I. O. Baker.

Although the building of pavements has been, for hundreds of years, one of the most important problems confronting municipal engineers and public officials, and despite the fact that the pavements in the larger American cities have cost the inhabitants more than $20.00 per capita of present population, the importance of this element in city finance does not seem to be fully appreciated. In American cities having a population of 30,000 or more, there are nearly 300,000,000 square yards of pavements of different kinds; but until recently no attempt was made to collect and preserve information in regard to them. That which has been collected so far is meagre and unsatisfactory and throws little or no light upon the various methods used in their construction or upon the very important consideration - their cost. The first cost and also the annual cost for maintenance of pavement is so great that from a pecuniary stand-point street pavements deserve the closest consideration and systematic study; and when measured by their influence upon the commercial, sanitary, or esthetic life of the city, they are an equally important municipal problem.

Pavements are usually constructed by companies or individuals working under contracts, with a city official as overseer. Both the contractor and the city official should be, and usually are, competent civil engineers. If they are not engineers, engineering talent must be employed. These two engineers look at the subject from opposite view-points. The city engineer's duty is to secure for the city the best possible pavement at the least possible cost, whereas the contractor's desire is to construct a pavement that will fulfill the requirements of the contract and net him the largest possible profit. These conflicting interests bring out two distinct phases of the subject. Accordingly this discussion will treat of methods in paving contracting as seen:

(1). From the stand-point of the city engineer.

(2). From the stand-point of the contractor.

## HISTORY OF PAVEMENTS.

Primeval man had no pavements nor any use for them but as the race developed into tribes and communities and the commercial spirit sprung up among them, the necessity of improved roads became apparent. The earliest pavement of which we have any record, if such may be called a pavement, is a stone causeway east of the Great Pyramid which was built by Pharaoh for the purpose of conveying stone and other materials across the sand for the construction of the pyramid. It was built about 4,000 B. C. The city of Carthage from 600 B. C. to 146 B. C. maintained a general system of paved roads and it was from them that the Romans learned the advantages of such roads. These roads, at first thought, might be considered expensive, but when it is considered that they were built by slave labor, it is easy to understand why so much needless labor was spent upon them. These roads were of solid masonry and often were several feet thick. The stones used were of irregular size and shape, and were laid in cement mortar so as to make them impervious to water. Their massive construction and the comparatively small amount of light traffic which they had to sustain, were greater factors tending toward centuries of service than was the road - building skill so often attributed to the Romans. Palestine, Mexico, Peru, Italy, and France built roads of much merit at very early times, but pavements in the true sense of the word are characteristic of the nineteenth and twentieth centuries.

Early in the nineteenth century several European cities built wheel tracks of large stones, with a road paved with smaller stones between the tracks. London, although the metropolis of England, was one of the slowest cities in making street improvements.

With the advent of Macadam and Telford, considerable broken-stone roads were laid in that city; and in 1825, a pavement consisting of a crushed-stone track for horses, laid between wheel tracks of broad, smooth, well-jointed granite blocks was built. The first attempt at a modern stone pavement was made on Blackfriars Bridge, London, in 1845. It consisted of 3X9X9 inch granite blocks set with mortar joints. The first asphalt to be used in street paving was on Threadneedle Street, London, in 1869. This rock asphalt proved to be very popular and several miles of it were laid during the next four years. Wood-block pavements made their first appearance in Glasgow, Scotland,in 1841; but with the exception of about a mile of London streets paved in 1873, this kind of material was little used until about 1890, when the method of construction was greatly improved.

Manchester was the pioneer city in the use of tar and gravel joints for block pavements, while London was the first to use concrete as a foundation material. Concrete,for this purpose, was first used in 1872 and three years later it had come into general use.

In America, prior to 1850, about the only paving material was cobble stones and macadam, although some experimental wooden-blocks were laid 15 years earlier. About this time a pavement of rectangular stone-blocks, one to two square feet in area, known as "Russ" blocks, was laid in New York and a few years later the blocks were grooved to give foot-hold to the horses.

Belgian blocks were first laid in 1852 and were extensively used for several years. Granite blocks of the shape now used, date from 1876. Coal-tar pavements have been repeatedly tried, always without success, for the past fifty years.

The first brick pavement, consisting of bricks set on edge on a foundation of cinders, was laid at Charleston, W. Va., in 1870. This experimental block of pavement was followed in 1873 by a block on the principal business street being paved with a good quality of building brick. In point of wearing quality, this pavement compares favorably with the best modern brick pavements.

In 1875, the block lying between Washington and Jefferson street, on Center St., Bloomington, Illinois, was paved with a poor grade of building brick, and although 36 years have elapsed since it was laid, part of this pavement is still in service as a foundation for a sheet asphalt pavement laid in 1906.

# PART 1.

## THE CITY ENGINEER'S PART IN PAVING CONTRACTING.

ORIGIN OF THE AGITATION FOR PAVEMENTS. Under the present law controlling public improvements in Illinois, city pavements come under the control of the board of local improvements of the city where the pavement is to be laid. In cities of less than 25,000 inhabitants this board consists of three members, while in cities larger than 25,000, the board consists of five members. In most cases, the city engineer is president of the board. The mayor is, by virtue of his office, a member of the board, and the remaining member or members are chosen from the city council. All members, including the president, have equal voting powers. The agitation for a desired pavement may originate with property owners along the street to be paved or it may originate with the board. Whether or not the pavement shall be laid, and, if so, the kind of pavement, its width, etc., are under the absolute control of the board.

THE PETITION AND THE SECURING OF FRONTAGE. Formerly, no block of pavement could be laid without the consent of the owners of a majority of the frontage in the block, but under the revised law, if public policy seems to demand it, the board may order a pavement to be laid in direct opposition to the wishes of the property owners. This, however, is seldom done. Probably a majority of the pavements are laid in compliance with petitions signed by the owners of a majority of the frontage along the entire length of the pavement and not by a majority in each block, as was formerly necessary. Under the old law, the property owners could control their pavement to the

minutest detail by properly wording their petition. They could specify the kind of pavement, the foundation, the curbing, the width, and other details that they, in their ignorance, might see fit to insert. Now, however, the petition serves only as an index to their wants and the board uses its more competent judgement as to what is best for each particular case. As an example, in Bloomington, Illinois, a city of 25,000, a brick pavement on W. Washington Street, was almost totally destroyed in fifteen years by the heavy hauling from the McLean County coal shaft. The property owners presented a petition for an asphalt pavement in the hope that so smooth a surface on the grade of the street would cause the heavy teaming to avoid the street and to travel other routes. A new pavement was absolutely necessary but the board decreed that the object of paving was to accommodate the traffic rather than to hinder it, and it laid a pavement of paving blocks with cement filler in the face of violent opposition from the owners. The city engineer in charge of this work is a man of ability and experience and he maintains that during a part of the year an asphalt pavement would render this street impossible for the heavy hauling that forms the greater part of its traffic. During the time that it would be passable, the wear would be heavier than an asphalt pavement could stand. Pavements of the kind adopted have been in use on similar streets for a number of years with such satisfactory results that it has been asserted by men competent to judge that no other kind of pavement has yet been devised that will give as good service under all conditions.

CONSIDERATIONS WHICH DETERMINE THE KIND OF PAVEMENT. There are many factors that enter into the selection of the kind of a pavement that should be laid on any particular street. Each city and each

division of the city presents its own problem. "A perfect pavement should satisfy the following conditions:

(1). It should be low in first cost.

(2). It should be durable, i.e., the cost of perpetually maintaining its surface in good condition should be small.

(3). It should have a smooth, hard surface so as to have a low tractive resistance.

(4). It should afford a good foothold to enable horses to draw heavy loads, and to prevent them from slipping and falling and possibly injuring themselves and blocking traffic.

(5). It should be smooth so as to be easily cleaned.

(6). It should be comparatively noiseless.

(7). It should be impervious, so as to keep in good sanitary condition.

(8). It should yield neither dust nor mud.

(9). It should be comfortable to those who ride over it.

(10). It should not absorb heat excessively."- Baker.

Such a perfect pavement can never be realized because of the antagonistic nature of the qualities required. As an example, a hard smooth pavement offers little tractive resistance, but a hard pavement is injurious to horses and a smooth one gives no foothold that will enable horses to draw heavy loads. A soft yielding pavement is least injurious to horses but offers great resistance to traction. The relative importance of each of the above qualities on the street to be paved must be determined and with these in view the kind of pavement selected.

The cost of a pavement is always one of the most important considerations. The cost of a pavement depends upon local conditions

to such an extent that it is impossible to make an exact statement of the cost of each kind; but the values given in the following table approximate the actual costs closely enough for comparison.

| Kind of Pavement. | Cost per square yard. |
|---|---|
| Gravel | $0.50 |
| Macadam | $0.75 |
| Brick | 1.65 |
| Wood block | 3.00 |
| Granite block | 3.50 |
| Sheet Asphalt | 2.75 |

The problem confronting the board of local improvements is to determine what kind of a pavement will give the best service with the fewest disadvantages. In many cases the board is "penny wise but dollar foolish". They lay too great importance upon a small saving in first cost. If it appears that a number of pavements will give practically equal satisfaction in a certain street, the cheapest one will be chosen, but in every case it should be ascertained if a larger investment will not give more than a proportionate increase in service. Lack of sufficient funds for the construction of the most economical pavements may make the item of first cost of such importance that inferior pavements will have to be selected.

The probable durability of the different kinds of pavements must be weighed against their first cost and the cost for upkeep to determine which is the most economical. The durability of a pavement depends chiefly upon the kind and volume of the traffic passing over it, although the effect of climate upon certain kinds of pavements is very marked. The climatic effect upon wood, asphalt, gravel, and macadam pavements is almost as great as the effect of the average

traffic to which such pavements are subjected. Asphalt pavements and wood-block pavements-- unless the wood is thoroughly preserved --decay quite rapidly if they are wet a very considerable part of the time, and for that reason are unsuitable for wet climates, for densely shaded streets, or for streets on which refuse is liable to retain moisture. Sand and macadam are not satisfactory in localities subject to high winds but are benefited by moisture. Very little systematic study has been made of the traffic upon pavements and the result is that traffic is usually referred to as "light" or "heavy"--a classification that is of but little help to the city engineer as a basis for his recommendations to the board of local improvements. The most satisfactory kind of a street-traffic census is one in which the average number of vehicles per day, their average weight, and the width of the streets are ascertained; and from these, the number of tons per foot of width per day are computed. By allowing for modifying conditions, such a census will admit of a comparison of the wearing qualities of all kinds of pavements. The average load of the vehicle is an exact index to the character of the street as is also the proportion of light and heavy vehicles. On residence streets, the average tonnage is light and the proportion of light loads is large, while on business streets the tonnage is heavy and the proportion of heavy loads is large. On an exclusive New York residence street over ninety per cent of the vehicles-- exclusive of automobiles which do very little damage to pavements--weigh less than one ton, while on several business streets in Chicago fully seventy-five per cent weigh more than one ton. On such streets as the former, the wear due to traffic is small and consideration of smoothness and of noiselessness outweigh the durability

On the latter class of pavements, the traffic is highly destructive and a durable pavement that will give good foothold for horses must be provided. The increasing use of rubber-tired motor-vehicles is changing somewhat the relative values of different kinds of pavements from the stand-point of durability. Gravel and macadam is unfit for a street on which there is a large amount of automobile traffic because the pneumatic tires tear up the loose material. A pavement with a smooth surface and a low tractive resistance is especially suited to the use of these vehicles. The calks that are used on horse-shoes in this country do great damage by cutting--especially when hauling heavy loads--and by chipping paving blocks. For these reasons, asphalt should never be selected for a street on which horses haul heavy loads; and if brick paving-blocks are used they should be filled with cement mortar. In cities where such an ordinance does not exist, the engineer should recommend to the city council as an important step in pavement economics, an ordinance regulating the load per unit width of tire that may be hauled.

ENGINEER'S ESTIMATES. Before the contract for a pavement is let and often before the kind of pavement is decided upon, the engineer makes a careful survey of the street. If the grade of the street is already determined, as is usually the case, the work of surveying is greatly reduced, for all that remains to be done is to locate the center-line of the pavement and the intersection points of cross streets, to set grade stakes, and to determine the amount of dirt that will have to be moved to bring the surface of the ground to the elevation and shape of the sub-grade. The number of linear feet of curbing, the number of square yards of surface material, the amount of sand required for the cusion, and the amount of concrete, sand, or tar required to fill the joints of block or brick pavements are all deter-

mined very carefully. The local prices of these items are fairly definite as is also the price of labor. All of the surveying is done with care and precision and from this information and the local prices, estimates of the cost of the different kinds of pavements that are under consideration are made. To the estimated cost ten per cent is added for profit. These estimates are used in determining what kind of a pavement to build and afterward they serve as a means of telling whether or not the bids received are unduly high. The amounts bid by the contractors are usually very close to the engineer's estimate. If the estimate is high, the bids are slightly below it. If it is low the bids are slightly above it. The engineer should therefore, figure as low as is consistent with fairness to the contractor as his estimate has considerable bearing upon what the pavement is to cost the city. Unless changes are made in the adopted plans, it is unnecessary to measure a finished pavement before paying for it as the estimate embodies all the necessary information.

THE CONTRACT. Aside from his duties as a member of the Board of Local Improvements, the engineer must draw up plans for the pavement, write the specification for its construction, and assist the city attorney in writing the contract. In doing these things, he can best protect the city's interests by writing everything so comprehensively as to leave no doubt as to the meaning of the contract and specifications. It is common for cities to have printed blank-forms for contracts for different kinds of pavements. The following paragraph, quoted from the contract used at Bloomington, Illinois, is typical of a clause that is written in every paving contract. "It is expressly understood and agreed that the entire improvement shall be done in a thorough and workmanlike manner under the direction of the City Engineer and the Board of Local Improvements, and to the entire satis-

faction of said Engineer and Board of Local Improvements. All losses or damage arising out of the nature of the work to be done or from any detention or other unforeseen obstruction or difficulties which may be encountered in the prosecution of the work, or from the action of the elements, shall be sustained by the contractor". Sewer inlets conforming to specifications, are furnished by the contractor and are placed at points designated by the City Engineer.

Whenever, by reason of the character of the soil encountered, it is deemed necessary by the Engineer so to do, sub-drains are constructed at such places and upon the lines and grades given. A minimum depth of about three feet is usually specified for such drains.

The contractor is commonly held responsible for damage done to water, gas, sewer, or drain pipes and appurtenances.

All material must be inspected and approved by the city inspector before it is used in the pavement.

In addition to these general specifications, all questions that may arise on the particular pavement under consideration should be anticipated and answered in the contract and specifications. When this is not carefully done, the contractor must add enough to his bid to cover unforeseen contingencies.

If, when the bids are opened, they are found to be too much above the Engineer's estimate, the Board of Local Improvement may reject them and advertise for new bids.

INSPECTING AND OVERSEEING. Since the work of paving is to be carried on under the direction of the city engineer, who can not be constantly present on any piece of work, inspectors must be provided who will act under the Engineer's direction. It is usual to provide in the contract that if the pavement is not completed within the time

stipulated in the contract or if in the estimation of the Engineer it is necessary to employ more than one inspector on a job in order to secure a faithful compliance with the contract, such extra inspector's pay shall be charged against the contractor

In order to prevent undue expense to the contractor, all defective material should be rejected by the inspector before it is placed in the pavement instead of causing it to be removed after it is in place.

Great care should be exercised to see that the earth is removed to the proper depth along the center line of the pavement. It is a common practice for contractors to leave the crown from one to three inches too high, claiming that it will "roll down". It has been shown conclusively that it will not "roll down" and the result of this "boosting" of the crown will produce one of the following defects:

(1). The concrete or other foundation will not be laid to the required thickness along the center.

(2). The sand cushion will be too thin along the center.

(3). The crown of the finished pavement will be too high.

Either (1) or (2) will be prohibitive of a first class pavement and (3) will, by making travel unpleasant along the sides of the street, cause the traffic to concentrate along the center of the pavement where deterioration will be rapid. The crown of a sheet asphalt pavement laid on S. Roosevelt Avenue, a residence street in Bloomington, Illinois, in 1907 was "boosted" about two and one half inches, and the effect of traffic is more noticeable there than on the up-town streets, where the same kind of a surface was laid at the same time on top of the old brick pavements.

Contractors sometimes try to use lean concrete for the pave-

ment foundations. By excessive tamping, the cement may be made to flush to the top, so that the surface will present the appearance of a rich mixture. The inspector should, by directly supervising the mixing of the concrete, assure himself that no such cheapening of the work takes place.

ACCEPTANCE OR REFUSAL OF THE PAVEMENT. If the work of inspection has been properly done, there is but little probability of the pavement's being rejected after it is completed and the contractor has complied with his agreements in regard to the removal of waste materials, debris, etc. In some cities it is customary to require the contractor to guarantee his work for a period of years and a part of the contract price is held until the expiration of such term. In the days when little was known about pavements, this may have been a wise precaution; but improved methods and advanced knowledge in regard to the construction of pavements, make it possible and advisable to safe-guard the public interests as effectively by efficient inspection during contruction without any prolonged guarantee.

Some engineers express the belief that guarantees extending longer than one year are unnecessary as defects will be noticeable in that time if any are likely to appear. A contractor will invariably add to his bid a sum sufficient to cover the expense of maintenance during the period of the guarantee, so that the city pays for the safeguard without receiving a corresponding benefit.

# Part II.

## PAVING FROM THE CONTRACTOR'S STANDPOINT.

FIGURING ON THE CONTRACT. The manner of advertising for bids for paving at Bloomington, Illinois, may be taken as a typical example. Before advertising for bids, the city engineer prepares a very careful estimate of the amount of materials of all kinds necessary to complete the work and of the amount of excavation and fill that will be necessary. This estimate and complete specifications are furnished to any bidder who desires them. The following blank is taken from the contract form used at Bloomington, Illinois.

(12) APPROXIMATE QUANTITIES.

These quantities are approximately correct and will be used in determining the lowest bid; but are subject to change in construction of the work.

.....Cubic yards of .....required.

.....Square yards of concrete foundation laid.

.....square yards of brick paving laid and filled.

.....square yards of brick paving to be taken up, re-laid and filled.

.....lineal feet of stone curbing to be set.

.....lineal feet of combined concrete curb and gutter.

.....lineal feet of concrete curb.

.....cast iron crossing plates to be furnished and set.

.....lineal feet of 12-inch inlet pipe to be laid, including connection.

.....lineal feet of.....sewer to be built.

.....cast iron inlets to be furnished and set.

.....old cast iron inlets to be reset.

.....new iron manhole rings and grates to be furnished and set.

.....lineal feet of old inlet pipe to be taken up and re-laid.

.....lineal feet of sub-drain to be laid complete.

.....new manholes complete.

All bids are required to be made under three heads as follows: (1). Materials only. (2). Labor only. (3). Materials and Labor combined. Contractors almost invariable prefer to take the contract for materials and labor combined, and they submit their bid in that class lower than the sum of their bids for labor only and for materials only. During recent years, no pavement has been laid in Bloomington under any except the combined contract, and this plan is the one most often followed in all cities.

Bids for excavation may be called for by either of two methods, (1) a unite price per square yard of surface area, and (2) a unit price per cubic yard of material moved. Method (1) is now obsolete. In bidding by the square yard, it would be necessary for the contractor to carefully survey the street to determine the amount of material he will have to move before he can bid intelligently. The second method relieves him of the necessity of surveying the street as he is paid the amount of his bid for the amount of material that the city engineer's measurements show to have been moved. The price bid for excavation includes the hauling that is necessary to dispose of the material wherever directed by the city engineer, provided that the haul does not exceed a stated distance, usually 2,000 feet. For distances greater than this additional pay is made. In Champaign and Urbana, this rate was formerly stated at two cents per 100 feet per cubic yard; but in over 20 years no haul has ever reached the limit of free haul so this clause has been stricken from all recent contracts. The cost of earth excavation in Illinois cities varies from 25 to 30 cents per cubic yard, depending upon the kind of earth, the depth of excavation, the price of labor, etc. On Nevada St., Urbana, the

price was 25 cents per cubic yard and on Washington St., Champaign, the price was 26 cents per cubic yard.

Catch Basins are usually five feet deep, and the cost is about $3.50 per foot of depth. Curbing is paid for by the linear foot. Stone curbing four inches thick and 20 inches deep costs about 40 cents per foot, while a combined concrete curb and gutter costs 46 to 50 cents per linear foot; but when it is considered that the latter narrows the width of the pavement required by 1 1/2 feet on each side of the street it is seen to be much cheaper. It also presents a much better appearance, is more easily cleaned, and is more sanitary.

Drains are usually constructed of eight-inch vitrified sewer pipe laid three feet deep and are paid for by the linear foot. At Champaign the price is about 20 cents per foot, with five to seven cents additional for each foot of depth beyond three feet.

For foundations a 1:12 concrete is commonly used, i.e., one part of cement to 12 parts of aggregate. Nearly all the aggregate used in the Twin City pavements is composed of equal parts of broken stone and of pit-run sand.

Each contractor submits his itemized bid according to the blank form shown on page 16. From the bids thus submitted the total cost of the pavement is computed and the bids compared as shown in Table 1, page 19, for State St., Champaign, and in Table 2, page 19, for Washington St., Champaign. The contract is awarded to the responsible bidder whose total, as based upon the city engineer's estimate, is the lowest.

WORK PRELIMINARY TO CONSTRUCTION. As all stakes are set by the city engineer, the only work that remains for the contractor to do before beginning the construction of a pavement is (1) to provide

# BIDS RECEIVED AT CHAMPAIGN, ILLINOIS FOR STATE STREET PAVEMENT. Aug. 18, 1903.

| ITEM | | QUANTITY | BIDDER | | | |
|---|---|---|---|---|---|---|
| | | | Thompson & Case. | | Stipes | |
| | | | Unit Price | Total. | Unit Price. | Total. |
| Excavation | | 2002 cu.yds | 26¢ | 520.52 | 25¢ | 500.50 |
| Stone curbing | new | 293 lin.ft. | 44¢ | 128.92 | 36¢ | 105.48 |
| | resetting. | 132 " " | 10¢ | 13.20 | 10¢ | 13.20 |
| Concrete curb & gutter. | | 4400 " " | 52¢ | 228800 | 48¢ | 2112.00 |
| 1 part Nat. cement | Culver Block | 6073 sq.yds | | | $1.41 | 8562.93 |
| 3 parts gravel & | Wobash Select | do. | | | $1.35 | 8198.55 |
| 3 parts broken stone | Poston Block | do. | | | $1.41 | 8562.93 |
| concrete founda- | Western Paver | do. | | | $1.35 | 8198.55 |
| tion, with | Clinton Brick | do. | $1.44½ | 8775.48 | $1.42 | 9623.66 |
| 15-in. drain pipe 3 ft. deep or less. | | 123 lin.ft. | 40¢ | 49.20 | 43¢ | 52.89 |
| Each foot increase in depth. | | | 7¢ | | 7¢ | |
| 12-in. drain pipe 3 ft. deep or less. | | 450 " " | 30¢ | 135.00 | 35¢ | 157.50 |
| Each foot increase in depth. | | | 7¢ | 63.00 | 6¢ | 54.00 |
| 10-in. drain pipe 3 ft. deep or less. | | 381 " " | 24¢ | 91.44 | 25¢ | 95.25 |
| Each foot increase in depth | | | 7¢ | 23.34 | 6¢ | 33.62 |
| 8-in. drain pipe 3 ft. deep or less. | | 100 " " | 20¢ | 20.00 | 20¢ | 20.00 |
| Each foot increase in depth | | | 6¢ | | 5¢ | |
| Catchbasins 3.5 dia. per foot | | 6 | $4.00 | 24.00 | $350 | 21.00 |
| Catchbasins 4.0 dia. per foot. | | 6 | $4.30 | | $3.90 | |
| Gutter plates | | 16 | $3.25 | 52.00 | $3.30 | 52.80 |
| | | | | | | |
| | | | | | | |
| | | | | | | |

UNIVERSITY OF ILLINOIS

Plate 2.

## BIDS RECEIVE AT CHAMPAIGN ILLINOIS FOR WASHINGTON STREET PAVEMENT JULY 21 1903

| ITEM | | QUANTITY | BIDDER | | | |
|---|---|---|---|---|---|---|
| | | | Thompson & Case | | J W Stipes | |
| | | | unit price | Total | Unit price | Total |
| Excavation | | 3012 cu.yds | $0.22 | $ 662.64 | $0.25 | $753.00 |
| Stone curbing | | 328 lin.ft | 040 | 131.20 | 0.36 | 118.08 |
| Concrete curb & gutter | | 4686 lin.ft. | 0.50 | 2343.00 | 0.47 | 2202.42 |
| Brick Paving on concrete foundation 1 part Port. Cement 8 parts gravel 8 parts broken stone | Clinton Brick | 6890 Sq.yds. | 1.61 | 11092.90 | 1.42 | 9783.70 |
| | Culver Block | 6890 Sqyds. | | | 1.42 | 9783.70 |
| | Western Paving Brick | 6890 Sqyds. | 1.43 | 9852.70 | 1.33 | 9163.70 |
| 15 inch drain pipe 3' deep or less | | 473 lin.ft. | 0.55 | 293.70 | 0.43 | 228.94 |
| For each foot increase in depth | | | 0.07 | | 0.07 | |
| 10 inch drain pipe 3 feet deep or less | | 660 lin.ft. | 0.28 | 307.75 | 025 | 271.36 |
| For each foot increase in depth | | | 0.07 | | 0.06 | |
| 8 inch drain pipe 3 feet deep or less | | 550 lin.ft. | 0.20 | 223.69 | 0.20 | 181.73 |
| For each foot increase in depth | | | 0.07 | | 0.06 | |
| For catch basins 3.5' diam per foot | | 7 | 2.40 | 84.00 | 3.50 | 122.50 |
| For catch basins 4.0' diam per foot | | | 2.70 | | 3.90 | |
| Gutter plates | | 36 | 2.90 | 104 40 | 3.30 | 118.80 |
| Total with Clinton Brick | | | | 15245 28 | | 13781.63 |
| Total with Western Paver | | | | 14005 08 | | 13160 53 |

for the underdrainage and (2) to prepare the subgrade to receive the foundation of the pavement.

In most cases, provision is made for carrying away the ground water and the surface water in the same drain. This may be accomplished by means of a large conduit under the center of the pavement or by means of a line of small pipe along each side of the pavement. The latter is preferable in most cases, since repairs may be made without tearing up the pavement. For the same reason, it is desirable to lay the drains under the parking just outside the curbing, where that is possible. The greatest care should be observed in making the grade of the drain as dirt will collect in all depressions. All ditches for tile and holes around catch basins should be carefully rammed in re-filling in order to prevent settlement after the pavement is built. No definite number of men can be said to be necessary for this work as the number will depend upon the amount of tile to be laid, the depth at which it is laid, and upon the length of time before the digging must be completed. Four to six men often comprise the drainage gang.

In preparing the subgrade, the method used depends upon the length of haul. If the dirt is to be moved only a short distance and over comparatively level ground, wheel scrapers are used to advantage; while if the haul is long or over rough ground wagons are more satisfactory. The gang required for this excavation consists of one foreman, six to eight teamsters, and an equal number of helpers, whether wagons or wheel scrapers are used, although as many as twelve wagons each with a driver and a helper are often used.

The earth is first loosened by means of plows to within three inches of the finished grade. After this loose material is removed

the subgrade is finished by means of a road grader or with pick and shovel. The former is usually the more economical and produces a more uniform surface. The finished sub-grade should be thoroughly compacted by rolling. The rolling process will cause depressions whereever there are soft places and where ditches have not been properly re-filled. These depressions should be filled and re-rolled until they are no longer noticeable. This work was formerly done by horse rollers but up-to-date contractors use steam rollers. The steam rollers give better results because of their greater weight and because they may be run transversely. Defective back-filling of trenches will be revealed by this transverse rolling. In justice to the contractor who is required to guarantee his work and to the citizens who have to pay for it, all gas and water mains that are likely to be needed for several years should be laid before the street is paved and the back-filling should be carefully watched.

Fills should be made with the best material available and should be thoroughly compacted by flooding and tamping. Cinders and gravel make good material for fills, but where the fill is of considerable depth, the material from the cuts is usually used. It should be rolled in layers four to six inches thick. No pay is due the contractor for fills unless he is obliged to borrow the material used in filling.

Curbing. The subject of curbing has already been referred to. In localities where bedded rock that may be easily split along smooth planes is found, the cheapness of this material will usually make its use advisable. In such cities as Champaign and Urbana, however, a stone curb costs nearly as much per linear foot as a concrete curb and gutter and is far less satisfactory from aesthetic and sanitary

standpoints, so that the latter is coming to be more and more popular. Keeping the stones of a curb in line has been the source of so much trouble that where concrete is used as a foundation, the curb is often set in a bed of concrete. The concrete curb and gutter is made by digging a trench 18 to 20 inches deep by 2 1/2 feet wide. In the bottom of this is deposited a layer of cinders four to eight inches thick which is flooded and thoroughly tamped. The forms are erected upon these cinders. Some contractors build alternate sections in boxes usually about six feet long, and after the boxes are removed planks are placed against these sections to make the forms for the remaining sections. Other contractors place a continuous line of plank in front of the gutter and back of the curb and set in thin partions to divide the curb into sections. The space between sections should be at least 1/8 of an inch to provide for expansion. The concrete for the gutter is laid and tamped and the facing applied. The form for the curb is then made by clamping against the upper part of the partitions a thin plank with a thicker one behind it. The concrete is deposited behind these and then the thin plank is removed. The facing is filled into the space thus left. As soon as the initial set begins, the forms are removed and the entire surface of the curb and gutter is troweled smooth. A 1:2:4 mixture gives good results for the concrete, and one part of Portland cement to two parts of sand is suitable for the facing. On this work practically the same number of men is used as on the other work incident to paving. A typical orgainzation and their pay is as follows:

1. foreman----------$3.00 per day.

6 men wheeling and tamping cinders----------.20 " hr.

2 men setting forms----------$.20 per hour.

6 men mixing and laying concrete----------.20 " "

2 men finishing.----------.20 " "

On large jobs these numbers would, of course, be increased but on S. Fourth St., Champaign, 17 men were at work most of the time. The curbing is always built before the excavation is done.

The Foundation. The foundation is that part of a pavement which rests directly upon the subsoil. Its purpose is to distribute the pressure of the loads uniformly over the subsoil. Although the foundation of a pavement is as important as the foundations of other structures, it is more often neglected. It makes no difference what kind of foundation is used it must rest directly on the subsoil. Therefore the subsoil should be thoroughly drained and compacted by rolling in order to give it the greatest possible bearing power.

Wood-block, and stone-block pavements were formerly laid upon beds of sand. This can hardly be called a foundation as the sand merely furnishes an easy means of bedding the blocks and bringing them all to their proper grade. A slight improvement over this method of laying wood-block pavements is to place a layer of planks on top of the sand and to set the blocks on this plank. With the increased cost of lumber, increased traffic, and improved methods of paving this kind of foundation is no longer used.

Formerly the foundations for brick pavements were formed by laying a course of bricks on their broad sides on top of a six- to eight-inch bed of sand or cinders. In rare instances this kind of foundation is still laid but with the decreased cost of Portland cement and improvements in its use, concrete foundations have come to be used for almost all foundations for pavements. Four to eight

laborers are required to lay such foundations.

A thick layer of macadam, gravel, or bituminous concrete made of a mixture of coal tar and broken stone can be used to advantage in localities where the material for such a foundation is especially plentiful or where cement is prohibitively expensive.

The advantages of a concrete foundation have been enumerated by Prof. I. O. Baker as follows:

1. It gives a smooth uniform surface upon which to lay the pavement.

2. It prevents the surface water from percolating to the subgrade.

3. By its thickness and resistance to flexure, it distributes the concentrated load over a considerable area of the subgrade.

4. Concrete acts as a bridge to support the pavement in case of a settlement of the subgrade.

5. Being impervious to water and a non-conductor of heat, concrete protects water and gas pipes from freezing.

The strongest concrete is obtained by using just enough cement to coat every particle of sand and gravel with cement paste. Since the cement is the weakest part of the concrete, the use of too much cement weakens the mixture. If the amount of cement used is insufficient to coat the aggregate or if the aggregate is not graded to give a minimum percentage of voids, the concrete will not have a maximum strength.

Broken stone, screened to uniform size, is sometimes used in concrete for foundations. Graded stone is cheaper because the particles fit closer together and less cement is required to fill the voids. It is easier to lay concrete made of graded sizes of stone,

as the uniform sizes tend to form arches while being rammed and a weaker foundation is the result.

At the present prices, it is usually specified that Portland cement only shall be used.

The thickness of the foundation must be sufficient to prevent its breaking through under loads, and it is false economy for a contractor to use his influence in favor of thin foundations. Six inches is sufficient thickness for residence streets, while for business streets eight inches should be used.

Wet concrete may be worked more easily and rapidly than dry concrete. For this reason, it is to a contractor's advantage to use as wet a mixture as is consistent with good work.

Nearly all pavement contractors mix concrete by machinery, since in this way the work is more quickly done and thorough mixing can be secured with proper supervision. The unit cost is about the same whether mixed by hand or machinery.

The gang that laid the foundation for the pavement on S. Fourth St., Champaign, may be taken as typical. It was organized as follows:

8 men shoveling sand and stone into the mixer.

4 men wheeling concrete from mixer to its place in the foundation.

1 man grading the foundation.

1 man tamping the concrete.

1 man carrying cement to the mixer.

1 man running the engine.

1 man cleaning up concrete spilled on the iron plate under the mouth of the mixer.

These men were all common laborers and received 20 cents per hour. The same forman was in charge at all states of the paving. The cost of labor on this job was about nine cents per square yard.

In mixing concrete by machinery, the output is controlled by the mixer and the foreman should study the situation carefully to determe whether he has too many, too few, or just enough men to keep the machine working at its most efficient rate. R. F. Dana, Consulting Engineer, cites an example of a small mixer, such as is used on pavement work, in which the time of mixing one batch of concrete was reduced by the seemingly trivial amount of 15 seconds; but yet this small saving resulted in an increase of 14 per cent in the out-put. At the rate of $5.00 to $8.00 per cubic yard of concrete this would mean a considerable increase in the daily profits.

Hand mixing is done on a board platform or on a metal plate from eight to ten feet square. The sand is spread out evenly over the middle of the mixing board, the proper proportion of cement is spread on top of the sand and the two are thoroughly mixed by turning two or three times with shovels. Water is sprinkled onto the mass during the turning which should be continued until the mortar is of uniform consistency. The stone is then added and the whole mass turned until every piece of stone is coated with the mortar. Four turnings after the stone is added is usually sufficient. When mixed by hand the concrete is shoveled from the board into place. The surface of the foundation is made parallel to the finished surface of the pavement by means of a curved template. For narrow pavements the ends of the template rest upon the curbs, but for wide pavements one end rests upon a scantling in the middle of the street as a long template would be unwieldy and lacking in stiffness.

The tops of small stakes driven at intervals of a few feet are generally used to guide the concrete laying instead of templates. After the concrete has been smoothed off to the desired thickness, it should be tamped with a rammer six to eight inches square and weighing 25 to 40 lbs., until mortar flushes to the top. When the foundation is completed, all loose fragments of rock that would interfere with the bearing of the paving-blocks should be picked off, and the concrete covered with an inch or more of sand to prevent the concrete from drying too rapidly. This precaution is too often neglected as many contractors do not appreciate its importance.

Cushion Layer. The purpose of the layer of sand between the wearing course of blocks or brick and the foundation is to secure a uniform bearing for the material of the wearing course. Two inches of sand is sufficient to fill all irregularities on the surface of the foundation and to permit the rolling of the surface of the pavement to properly embed it in the sand. This thickness permits the sand to flow sufficiently to fill in the inequalities of the brick and is the thickness now almost always used.

After the sand for the cushion layer has been spread to approximately the proper depth, it should be smoothed to the exact shape of the finished surface by means of templates similar to those used in shaping the concrete foundation. For pavements 30 feet wide, or narrower, templates extending from curb to curb are used, but for wider pavements templates covering half or one quarter of the width are used. In cases where it is impracticable to use a single template extending across the entire street, the ends not resting on the curb or gutter must be carried on screeds made by embedding plank

in the sand to such a depth that the surface of the screeds conform to the finished surface of the cushion. The template should be provided with rollers at the ends to facilitate its movement. The templates are formed by cutting out to the shape of the finished pavement the edge of a plank two inches thick and of sufficient width to be rigid after the cutting. The plank must be braced to prevent sagging and bending, and substantial handles by which it can be moved backward or forward must be provided at each end. Hand power is sometimes used to draw the template although many contractors use horse power for this purpose. Two laborers at 20 cents per hour are sufficient for laying the sand cushion on pavements of average width when the template is drawn by horses.

The Wearing Surface. The method of constructing the wearing surface depends upon the kind of material used in its construction. As brick pavements are by far the most common in Illinois, this discussion will deal primarily with brick paving.

Where brick can be provided directly from the kiln as it is needed, a small saving may be effected by taking the brick directly from the wagons to the men who lay them. This is seldom practicable and on most jobs the bricks are unloaded along the side of the street before the grading is commenced.

Two men are usually employed in laying the brick on the sand cushion. The bricks are commonly delivered to the brick-setters by means of wheel-barrows or on boards about six inches wide and two feet long. The latter method delivers the brick convenient to the men, is cheaper, and chips the brick less. Six or seven helpers are necessary to keep the brick setters busy by either of these methods. Mr. J. W. Stipes of Champaign, Illinois, has devised a

convenient method of displacing both the wheel-barrows and the boards, and at the same time reduces the number of helpers to four, with even greater saving in regard to chipping the brick. This device consists of a series of parallel wooden rollers about two inches in diameter and 15 inches long which are set about one-quarter of an inch apart. These rollers turn about axles the ends of which are held in two parallel wooden strips about two inches thick, three inches deep, and 15 to 18 feet long. One of these nests of rollers is placed on each side of the street--one end resting on the pavement near the middle of the street and the other supported two and one-half to three feet above the curbing. One man transfers the brick from the pile to the rollers while another removes them and stacks them convenient to the brick-setter after gravity has caused them to pass over the rollers to the lower end of the incline. Four men are thus able to do the work of six or seven and to do it without injury to the brick. These nests of rollers cost about $5.00 each, but the saving in labor will pay for them in a single day.

In some cities the brick are laid in courses, making an angle of 45 degrees with the length of the street. Cutting the bricks to fit along the gutter is wasteful of time and material. The diagonal courses are hard to lay and they give poor foot-hold for horses. They possess no advantages over bricks laid at right angles to the curb and for this reason the latter is in more common use except at street intersections where it is advantageous to compromise between the directions of the courses in the two streets. Street intersections are subjected to traffic of two streets and should therefore be laid with additional care. The sand cushion should never be disturbed, and to prevent this, the brick-setter should stand on the

bricks already laid. The bricks should be set on edge. A slight swinging motion helps to set the brick closely and compactly against each other. No material can be used to fill the joints that will be as durable as the brick, hence the joints should be as thin as possible. The bond should be half a brick. Bats should be used only in making closures, and in such places the brick should be broken to such size as will make a tight fit. Broken brick should be replaced before the joints are filled. Tongs with broad flat noses and strong handles will remove damaged brick without injury to those around it.

After all the bricks are found to be satisfactory, the pavement should be rolled with a steam roller weighing three to five tons. By this means the bricks are settled uniformly into the sand cushion, the top surfaces of the bricks are brought to a plane so that the effect of the traffic in chipping the brick is reduced, and the noisiness of the pavement is minimized. In places where the pavement can not be rolled, as around manholes, etc., the pavement should be thoroughly settled by ramming.

The Filler. The spaces between the brick should be filled to prevent the chipping of the edges, to keep the brick in position, and to render the pavement impervious to water. The materials used for this purpose are sand, cement, tar and asphalt.

Sand, for this purpose, should be fine and dry. The joints are filled by sweeping the sand over the pavement and by leaving a thin layer on top, part of which will be forced into the joints by traffic. Such a filler has the advantages of cheapness, ease with which damaged bricks may be replaced, and the rapidity with which the pavement may be made ready for service. There is danger of

the sand being washed out on steep slopes and it offers little protection to the edges of the brick.

Cement may be used for a filler either neat or in a mortar made of one part of Portland cement to one part of fine sand. Both must be mixed thin in order that it may flow readily into the joints. It should be mixed in small batches in tight boxes with legs of unequal length so that the mixture will flow to one corner of the box. Boxes for this purpose are about half the size of the ordinary plasterers' mortar-box. A second filling of a thicker mortar laid half an hour after the first gives good results. A thin layer of fine sand should be sprinkled over the filler, and if the weather is hot, the surface should be sprinkled occasionly to prevent too rapid vaporization. Traffic should not be allowed on the pavement for at least a week, as a cement filler that has been disturbed before it has set is no better than a sand filler. If it is not disturbed, the cement will wear as long as the best brick. Mr. Elmer Folson, City Engineer of Bloomington, Illinois, is authority for the statement that a brick pavement carefully constructed and properly filled with cement comes nearer than any other to meeting all the conditions of an ideal pavement. It is cheaper than almost any other kind of pavement, is more durable than any except the best stone pavements, offers little tractive resistance, is as noiseless as any except an asphalt pavement, is easily cleaned, and gives sufficient foothold to enable horses to draw any reasonable load.

Tar and asphalt fillers are laid in much the same manner. The material is shipped in the solid form in barrels. The night watchman on the works breaks open enough of the barrels for the ensuing day, cuts the material into pieces of convenient size for handling,

either with an axe or by drawing a wire tightly about them, and puts the pieces into a large tank with a fire under it, where they are melted. The pouring into the joints is done by means of a funnel-shaped vessel with a small neck which allows the material to flow into the joints as the vessel is carried along above them. Eight to ten men are used in pouring the material into the joints, two men keep them supplied with the material, and one man fires the melting pot. Asphalt fillers cost about eight cents per yard more than a concrete filler while tar-fillers cost about the same as concrete.

Expansion Joints. Where cement filler is used, expansion joints one-half to one inch wide are placed along the curbing and across the street at intervals of 100 feet. These joints make it possible for expansion of the bricks to take place without raising the pavement off of its foundation. At Indianapolis, Indiana, a wood-block pavement in which expansion joints were inadequate, was raised nearly three feet above the foundation due to temperature expansion.

Maintenance. In most cities, the city engineer estimates at the end of each month the amount of work done in the preceding month and the contractor is paid 80 per cent of the value of the same. On all classes of pavement except asphalt, it is customary to pay the contractor in full upon the completion of his contract. He is required, however, to give bond to insure a proper maintenance of the pavement during the five year period that he is required to guarantee his work. On asphalt pavements five to ten per cent of the contract price is withheld until the guarantee is fulfilled.

CONCLUSION. In recent years the National Paving Brick Manufacturers' Association and an organization including the contractors of Illinois have done much to improve the pavements of the state. Both of these organizations are studying pavements and paving materials in a systematic manner. In this way much has been done to improve the methods of paving contracting. Whenever either of these associations find that a contractor is dishonest or incompetent, they set about driving him out of the business. Several such contractors have been forced out in this manner since these organizations were started. The result of such organization is that the cost of pavements has advanced slightly but their quality has been more than proportionally improved.

Mr. J. W. Stipes, who has been building pavements in Champaign and Urbana for more than a score of years, speaks with pride of the manner in which these cities have improved and of the part that he has had in building them up. In addition to this he has acquired a competency and at the same time he has acquired a reputation for honesty and ability in his line of business that is an even greater asset. For this reason a man who expects to make a business of building pavements can not afford to give the city for which he is working anything but careful work, good materials, and a square deal at all times.

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